

## 5. IMPACT OF PLANT COMBUSTION EFFLUENTS

### SUMMARY

The evaluation of the impact of furnace combustion effluents consists of determining the ground level concentration (GLC) of pollutants from Dickerson in a region in which Dickerson and its proposed expansion will be the major emitters. The impact has been quantified by comparing the ground level concentrations of pollutants with the values and occurrence frequencies permitted by the applicable State of Maryland Standards. (Ref. 5-1)

The description of dispersion modeling and the meteorological data acquisition programs appearing in the April 30, 1973, Dickerson Report (Ref. 5-2) remain valid descriptions of the techniques utilized in the evaluation. However, additional work has been done in the area of model tuning, and this work has resulted in lesser predicted impact than that reported earlier (Ref. 5-2). This result was expected, since the earlier report (Ref. 5-2) had been cautiously conservative in all areas in which additional data were required.

The retuning of the model and the techniques developed to derive the hourly averages from the 5-minute averages used in tuning, utilize data from a 300-foot tower at Dickerson. These data were not available at the time of issue of the earlier Dickerson Report (Ref. 5-2). Using the new tuning and conversion factors, together with the prescribed 90% SO<sub>2</sub> scrubbing effectiveness, 99.5% particulate removal, and the plant and fuel parameters of Table 5-8, it is concluded that:

- a. The use of 850-foot stacks on the proposed units comes extremely close to providing compliance with the administrative guideline that no single emitter be allowed to exceed 50% of the 1-hour standard more than one hour per month (our data puts the 50% level at 55 ppb rather than 50 ppb)\*. The modelling indicates that this result is valid for the entire complex, as proposed, (i.e., the existing PEPCO plant plus two 850 MWe additions) and also with the existing plant emissions discharged through 400-foot stacks. However,

\*However, reheat is not recommended because the excess (5 ppb) is within the noise level of the calculations and because the administrative guideline is fully met at every individual point.

the use of an 850-foot stack on the existing unit is also highly desirable in that it provides a margin for operation within standards in the event of scrubber failure or the use of coal with sulfur content in excess of 2%.

- b. All other time averages  $\text{SO}_2$  GLC's are well within the 50% guidelines.
- c. The calculated values of  $\text{NO}_2$  ground level concentration on an annual average basis are everywhere less than 10% of the values permitted by Maryland Standards. There are no  $\text{NO}_2$  standards for shorter averaging times.
- d. Gaseous fluoride at its greatest level is less than 6% of the 24-hour standard and less than 25% of the 72-hour standard.
- e. Ground level particulate values predicted are less than 5% of the allowed 24-hour standard values and less than 1% of the allowed annual values.

#### POLLUTION DISPERSION

##### Tuning for 5-minute average GLC's

For five months during 1972-73, APL and EMI<sup>1</sup> conducted full-scale field monitoring at the Dickerson power plant. As detailed in Table 5-1, data included ground-level and overburden  $\text{SO}_2$  measurements, plant operating data, and surface and upper-level meteorological measurements. The EMI ground-level  $\text{SO}_2$  traverses were processed to define each instantaneous plume, and a 5-minute average peak concentration was computed as shown in Figure 5-1a and 5-1b for each Gaussian plume. This produced 128 measured values which could be compared with those 5-minute concentrations predicted by the Gaussian plume formula.

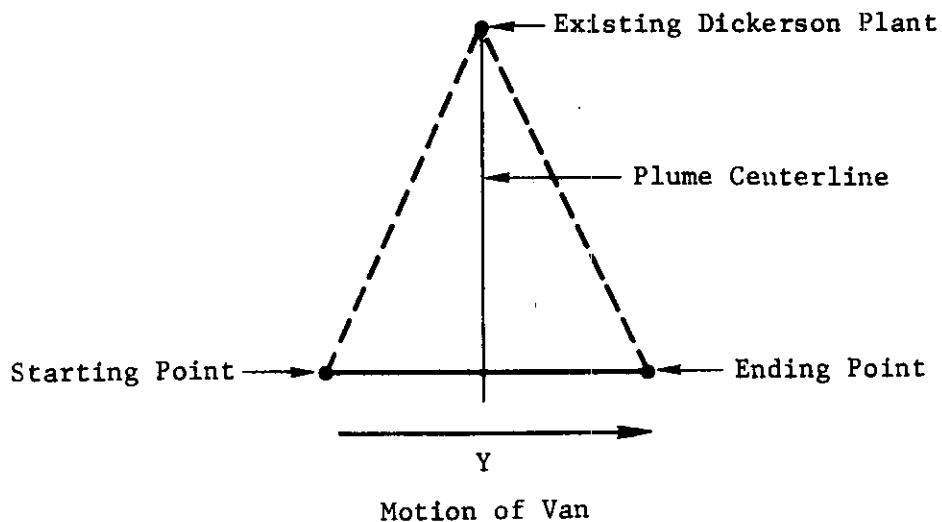
The initial comparison, using the Gaussian plume formula unchanged, showed severe underpredictions, by as much as two orders of magnitude. The Gaussian formula was then modified to account for topography by assuming the center of the plume remained at constant height above mean sea level and that hills and valleys brought the ground nearer and

<sup>1</sup> Environmental Measurements Incorporated - Operating under Contract to Maryland Department of Natural Resources.

TABLE 5-1

INPUTS TO MODEL TUNING

| Input   | Source  | Time Period<br>Used                                     | Information<br>Obtained   |
|---|---|---|---|
| Pibal/Radiosonde<br>Aircraft<br>Soundings   | APL Field<br>Program  | 11/72-2/73<br>3/73-4/73                                 | Upper Level Winds, Ambient<br>Temperature, Temperature<br>Lapse Rate, Inversion Heights |
| Local Climato-<br>logical Data  | Dulles<br>Airport   | Every Three<br>Hours Between<br>11/72-2/73<br>3/73-4/73 | Turner Stability Class  |
| SO <sub>2</sub> Ground Level<br>and Overburden<br>Measurements  | EMI   | 11/72-2/73<br>3/73-4/73                                 | Measurements of Peak<br>Axial Concentrations  |
| Plant Operating<br>Logs   | Dickerson<br>Plant<br>Office  | 11/72-2/73<br>3/73-4/73                                 | Hourly Plant Emission<br>Parameters   |
| Topographical<br>Maps of<br>Maryland-<br>Virginia<br>Area<br><br><u>Scales:</u><br>1:24000-1968<br>1:250,000-1957<br>(Revised 1969) | U.S. De-<br>partment<br>of<br>Interior,<br>U.S. Geo-<br>logical<br>Survey |   | Average Topography in 540<br>Zones in 20 Mile Radius<br>of Dickerson Plant              |



Record of  $\text{SO}_2$  GLC as Van Moves in Y Direction

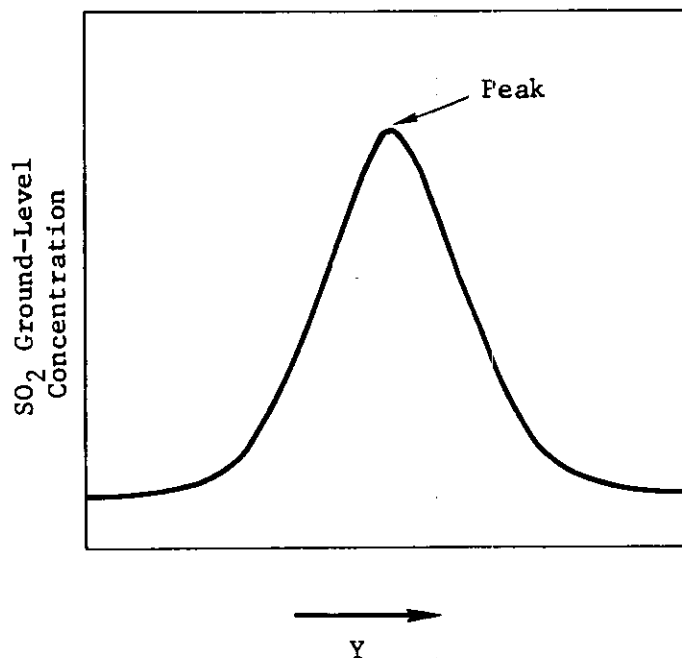


Fig. 5-1a. PLUME TRAVERSE METHOD

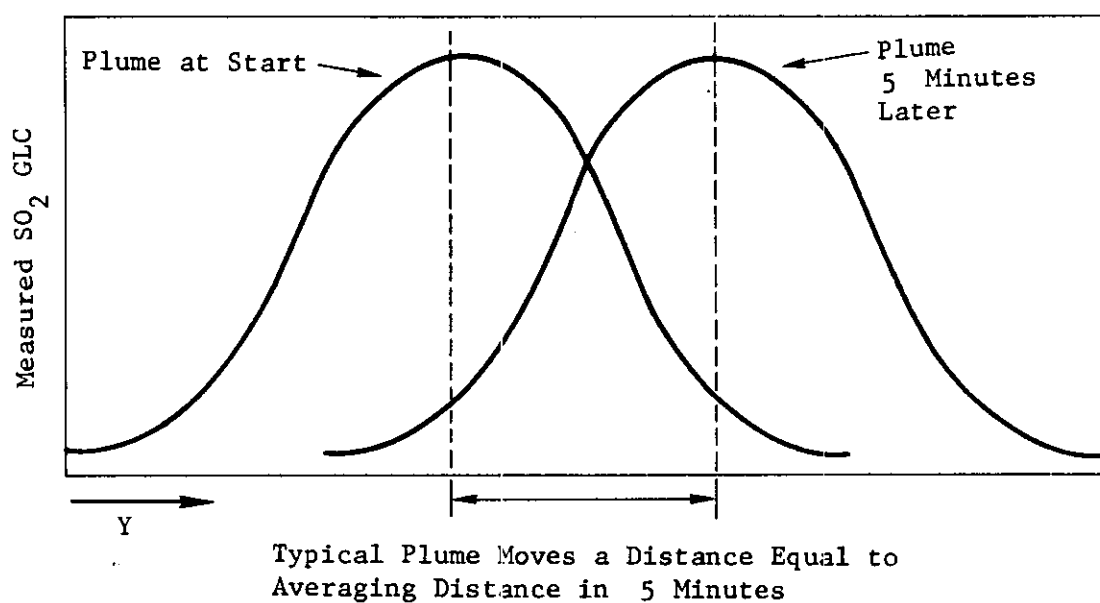
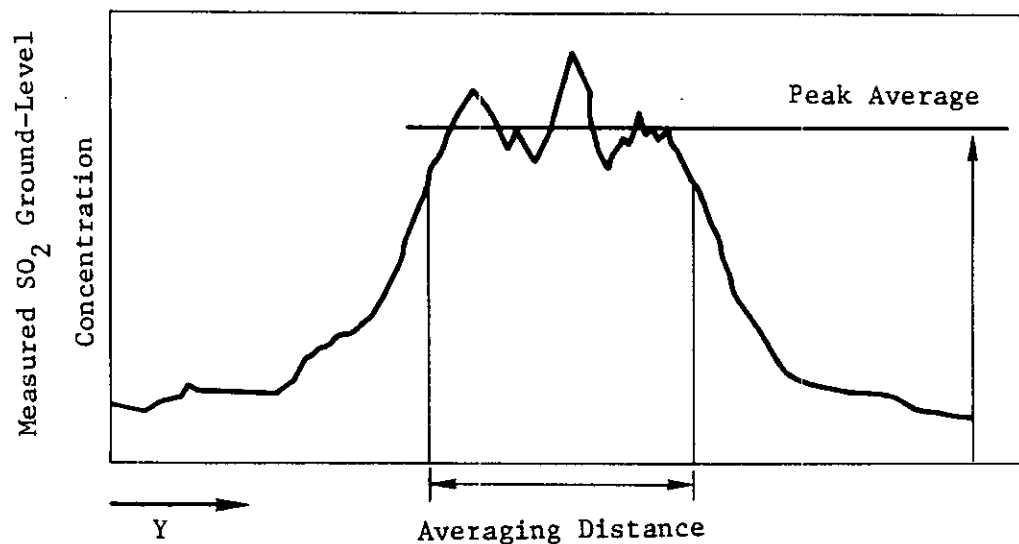


Fig.5-1b. CALCULATION OF PEAK AVERAGE

farther from the plume's centerline (Ref. 5-2), (see Figures 5-2a and 5-2b). Although this reduced the underprediction, the problem still existed, most significantly nearer the plant.

Because calculations for points near the plant are very sensitive to Turner stability class, large changes in near-field predicted values occur when the Turner stability class is shifted by just one class in either direction. It was concluded that the Turner stability class - which is determined at Dulles airport - might be inappropriate for Dickerson. Further, because surface roughness is known to increase atmospheric turbulence, it was plausible that the relatively rough topography of the Dickerson area might be a primary reason for a difference between the stability class determined at Dulles and that actually existing at Dickerson. It was decided to rerun the model predictions with the topography and with the stability class as derived from Dulles data shifted to the next most unstable class. This produced very good agreement with all 128 measured concentrations in both the near and far fields.

Figure 5-3 shows the observed-versus-predicted results of the basic tuning (with topography and stability class shift). Detailed analysis revealed that the overall distribution showed a significant bias toward overprediction, and that the model was overpredicting in the region of the administrative guideline at the 50 ppb level. It was decided to use fine tuning to refine these predictions. Specifically, a multiplicative factor of 0.8 applied to all predictions was found to reduce the overall bias as well as that in the 50 ppb region, while maintaining a safety margin of about +20% overprediction. Figure 5-4 shows the results of the basic and fine tuning.

Two special topics will now be discussed. First, a study was done to clarify the finding that the class of atmospheric turbulence at Dickerson was more unstable than that computed using Dulles airport surface data. This is a verification study of an empirical relationship already established on the basis of actual measurements at Dickerson. Second, the fine tuning methods are discussed in more detail.

Dulles-Dickerson stability class comparison. In order to compare Dulles stability classes with the actual turbulence existing at Dickerson, Dulles stability classes were computed every 3 hours during the month of June, 1973.

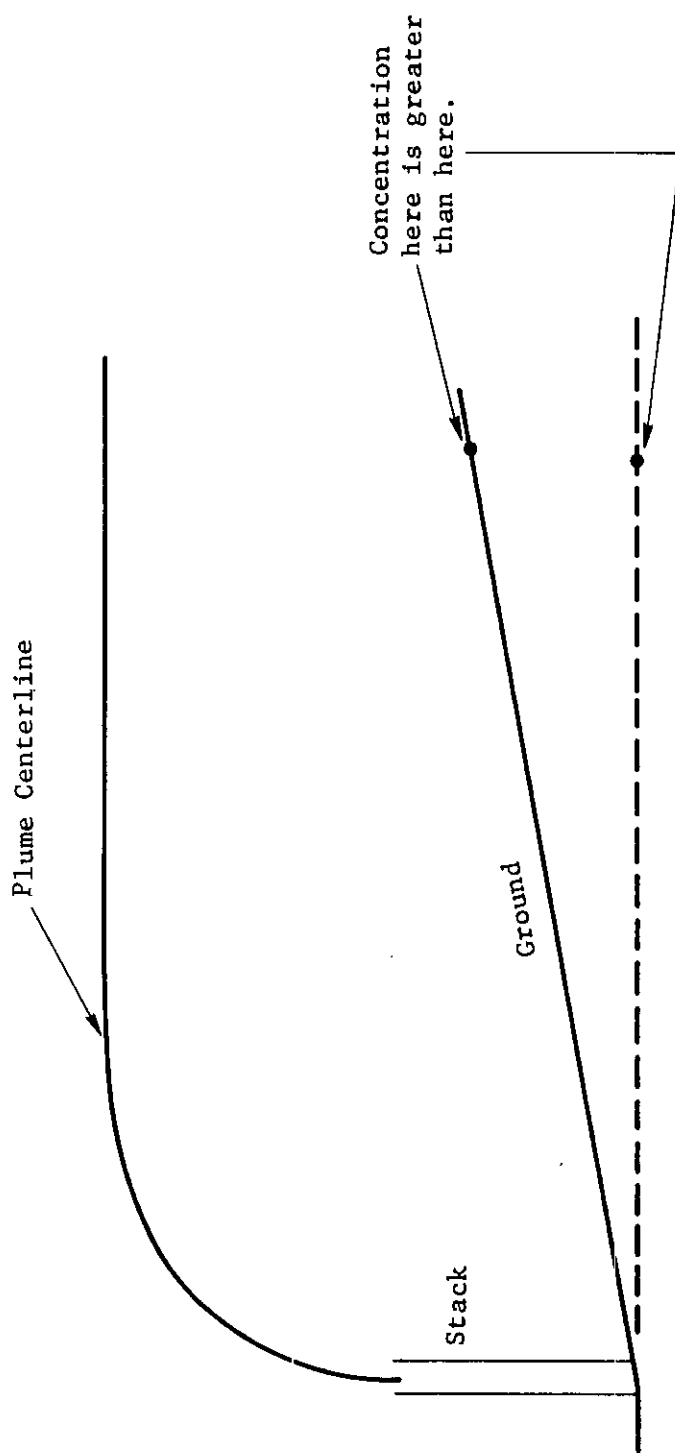


Fig. 5-2a. EFFECT OF TOPOGRAPHY ON GROUND-LEVEL CONCENTRATIONS

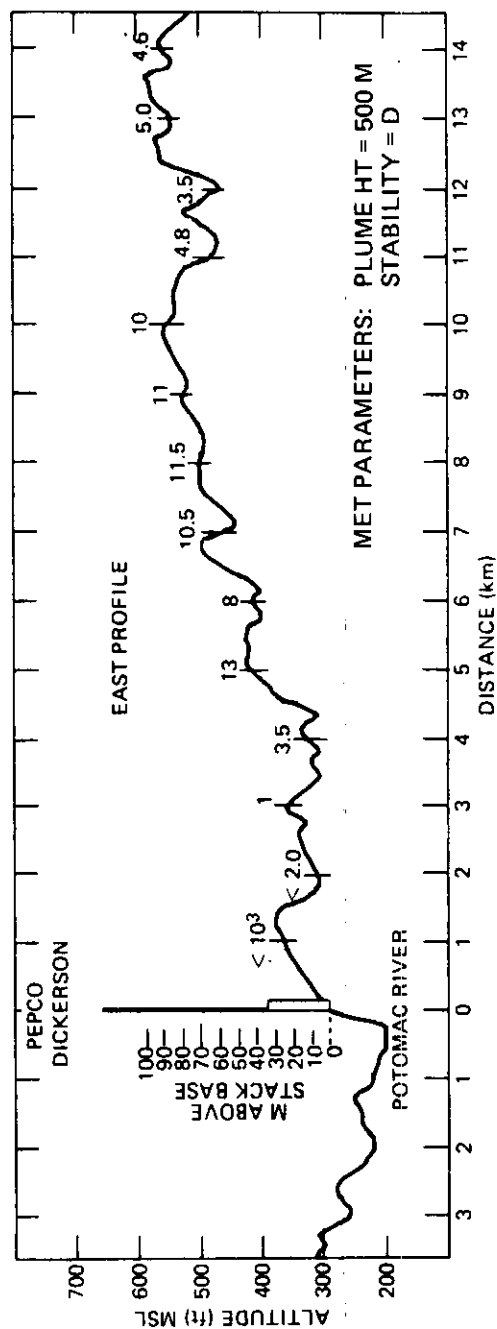


Fig. 5-2b INCREASE IN GLC DUE TO TOPOGRAPHY AS FUNCTION OF  
DISTANCE AND TERRAIN HEIGHT EAST OF THE PEPCO  
DICKERSON POWER PLANT FOR TYPICAL CASE.

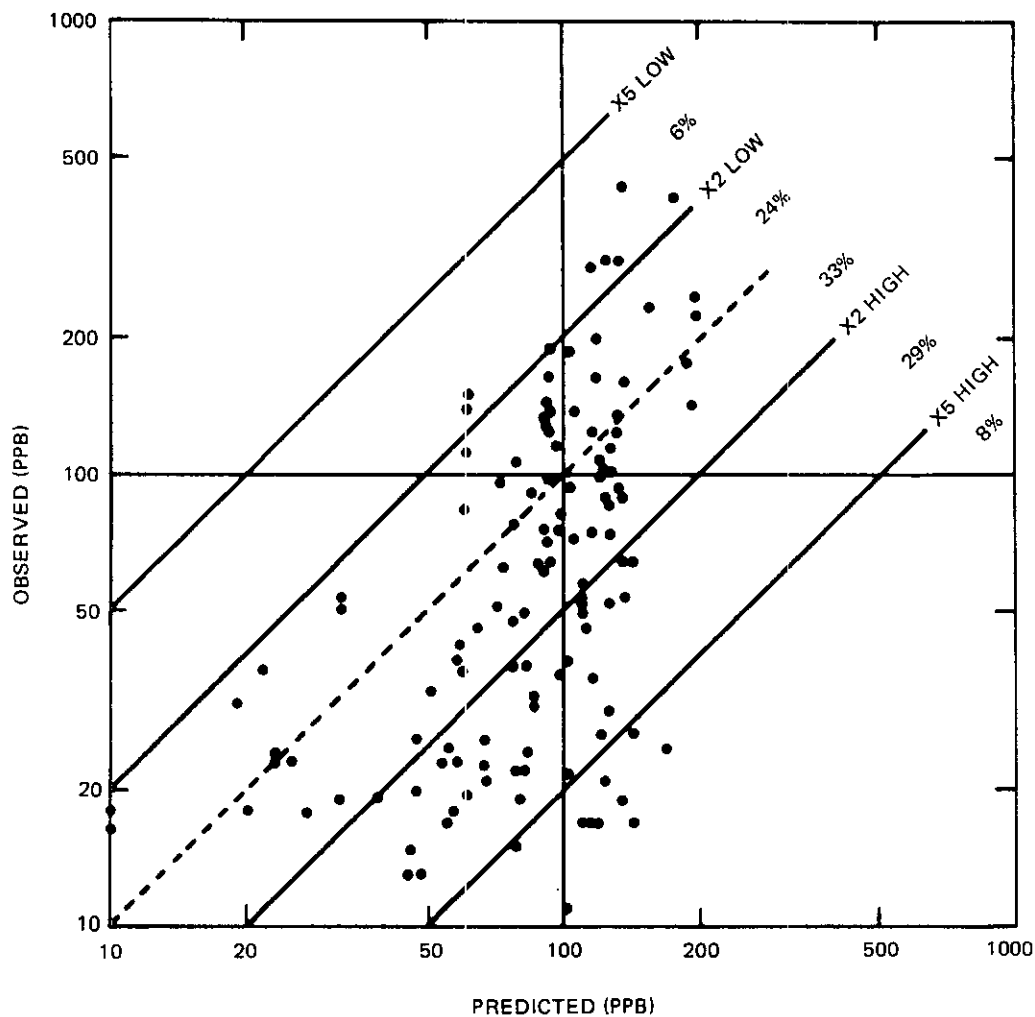


Fig. 5-3 BEFORE 0.8 TUNING FACTOR FOR 5 MIN AVE GLC  
(INCLUDES TOPOGRAPHY AND STABILITY CLASS  
CHANGE; BASED ON 128 TUNING POINTS)

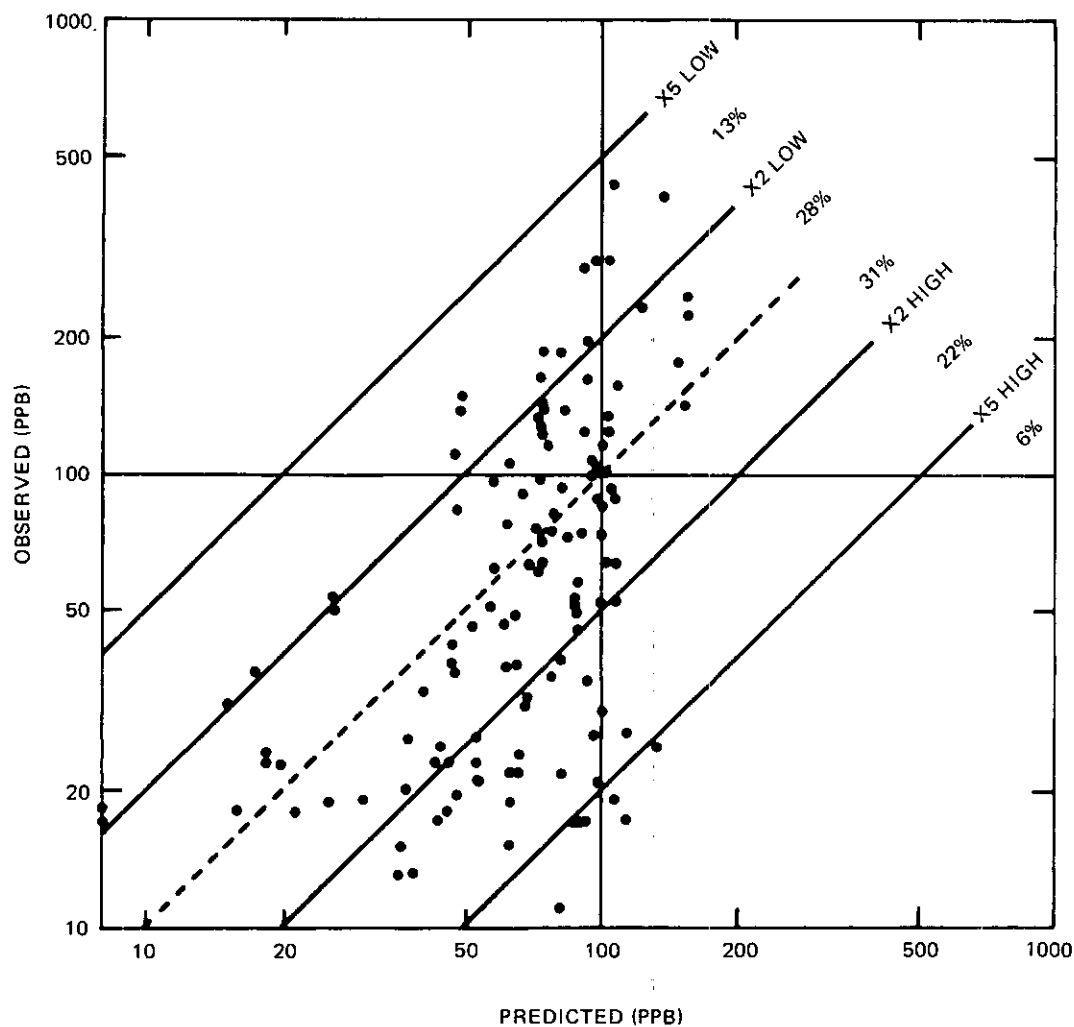


Fig. 5-4 RESULTS OF MODEL TUNING FOR 5 MIN AVE GLC. INCLUDES 1) TOPOGRAPHY, 2) STABILITY CLASS CHANGE, AND 3) 0.8 TUNING FACTOR. (BASED ON 128 TUNING POINTS)

Then for each such Dulles stability class, the standard deviation of the fluctuation of horizontal wind direction (sigma theta) was computed from the lower and upper level (10 m and 100 m) tower winds at Dickerson for 3 ten-minute periods centered around the Dulles reading:

| <u>Dulles reading time</u> | <u>Computation periods for<br/>Dickerson tower 10-minute<br/>sigma thetas</u> |
|----------------------------|---|
| 1300                       | 1245 - 1255<br>1255 - 1305<br>1305 - 1315                                     |

The 10-minute sigma thetas were computed with a wind direction sample once every 10 seconds; the mean direction was taken as the direction of the vector resultant of the 10-second vector winds. Each sigma theta was classified by stability class according to the scheme given by Slade (Ref. 5-3).

| <u>Sigma theta<br/>(Deg)</u> | <u>Stability class</u> |                 |
|------------------------------|------------------------|-----------------|
| 25.0                         | 1 (A)                  | (Very unstable) |
| 20.0                         | 2 (B)                  |                 |
| 15.0                         | 3 (C)                  |                 |
| 10.0                         | 4 (D)                  |                 |
| 5.0                          | 5 (E)                  |                 |
| 2.5                          | 6 (F)                  | (Very stable)   |

The clearest result of the comparison is that no one stability class can really characterize Dickerson turbulence during a 30-minute period. The three separate 10-minute sigma thetas vary widely, sometimes over all six stability classes. In order to determine whether the actual turbulence tends to be more unstable than Dulles, two quantities were tabulated. First, for each 30-minute period, the median (middle) value of the triple of Dickerson tower stability classes was tabulated against the Dulles class. Shown in Table 5-2a for the lower level winds, the distribution shows that generally, the lower level Dickerson turbulence tends to be more unstable than Dulles, i.e., Dickerson medians are more often less stable than their respective Dulles classes. The one exception is Dulles class 3, where Dickerson medians are larger a majority of the time.

The second quantity tabulated was the average time

distribution of the Dickerson tower stability classes against Dulles classes. This measured the average time (out of each 30-minute period) that the Dickerson atmosphere resided in lesser, equal, and greater classes than the Dulles class. This distribution is shown in Table 5-2b for the lower level winds and is very similar to the median distribution (Table 5-2a). It differs from the median distribution in that it reflects the entire 30 minutes of each period, whereas the median distribution considered only one 10-minute period from each (although perhaps the most representative 10 minutes). Clearly, except for class 3, the lower atmosphere spends more time in more unstable classes than in more stable classes, thus indicating the bias toward instability existing in the lower level.

In contrast to Dickerson lower level, Dickerson upper level tends to be more stable than Dulles stability class. The median and time distributions for the 100-meter level are given in Tables 5-2c and 5-2d and show that the atmosphere at 100 meters tends to spend most of the time in classes which are more stable than those determined from Dulles surface data. This is certainly plausible because Dulles stability class is an indicator of low-level turbulence over flat land, and we normally expect less turbulence at altitude. Dickerson topography causes "extra" low-level turbulence and is thought to produce the unstable bias in the lower level; but this ground-level mechanical turbulence will have dissipated considerably by the time it reaches an altitude of 100 meters.

It should be noted that turbulence at all levels is involved as pollutants are dispersed to the ground but that the modelling utilizes a single turbulence class. The fact that the lower level is less stable and the upper level is more stable than Dulles presents a problem as to the appropriate stability to be used in the predictive model. As indicated earlier, we have found that using a stability class, one class more unstable than Dulles, produces better agreement with our measurements. Although this agreement was based on monitoring a 400-ft. source, the shift towards less stability can only cause the predictions to be more conservative for higher stacks.

Fine tuning. To refine the predictive capability of the Gaussian model, it was decided to use a single multiplicative factor applied uniformly to all predictions. The selection of this factor was accomplished by using two types of tests: 1) measures of overall bias, and 2) measures of bias in specific regions: in our case, the region of the administrative guideline around 50 ppb.

TABLE 5-2a

COMPARISON OF DULLES AND DICKERSON STABILITY CLASSES -  
DISTRIBUTION OF MEDIAN DICKERSON CLASSES

(Based on Lower Level Winds for 197 Hours in June 1973)

| Dulles<br>Stability<br>Class | % of<br>Total<br>Hours<br>Having<br>Dulles<br>Stab. Class | % of Hours for Which Median<br>Dickerson Stab. Class Had Given<br>Relation to Dulles Stab. Class |                    |                     |
|------------------------------|---|--|--------------------|---------------------|
|                              |   | Less Than<br>Dulles  | Equal to<br>Dulles | More Than<br>Dulles |
| 1                            | 1   | *  | 67                 | 33                  |
| 2                            | 12  | 65   | 5                  | 30                  |
| 3                            | 16  | 32   | 7                  | 61                  |
| 4                            | 48  | 42   | 35                 | 23                  |
| 5                            | 10  | 75   | 25                 | 0                   |
| 6                            | 10  | 100  | 0                  | *                   |
| 7                            | 3   | 100  | *                  | *                   |

\*The algorithm used for computing Dickerson Tower stability class had no provision for stability classes less than 1 nor greater than 6.

TABLE 5-2b

COMPARISON OF DULLES AND DICKERSON STABILITY CLASSES -  
TIME DISTRIBUTION OF DICKERSON CLASSES

(Based on Lower Level Winds for 197 Hours in June, 1973)

| Dulles<br>Stability<br>Class | % of<br>Total<br>Hours<br>Having<br>Dulles<br>Stab. Class | Average # of Minutes Out of Each<br>30-Min. Period for Which Dickerson<br>Stab. Class had Given Relation to<br>Dulles Stab. Class |                    |                     |
|------------------------------|---|---|--------------------|---------------------|
|                              |   | Less Than<br>Dulles   | Equal to<br>Dulles | More Than<br>Dulles |
| 1                            | 1   | *   | 20                 | 10                  |
| 2                            | 12  | 17  | 2                  | 11                  |
| 3                            | 16  | 8   | 3                  | 19                  |
| 4                            | 48  | 13  | 10                 | 7                   |
| 5                            | 10  | 21  | 9                  | 0                   |
| 6                            | 10  | 27  | 3                  | *                   |
| 7                            | 3   | 30  | *                  | *                   |

\*The algorithm used for computing Dickerson Tower stability class had no provision for stability classes less than 1 nor greater than 6.

TABLE 5-2c

COMPARISON OF DULLES AND DICKERSON STABILITY CLASSES -  
DISTRIBUTION OF MEDIAN DICKERSON CLASSES (UPPER LEVEL)

(Based on Upper Level Winds for 197 Hours in June, 1973)

| Dulles<br>Stability<br>Class | % of<br>Total<br>Hours<br>Having<br>Dulles<br>Stab. Class | % of Hours for Which Median<br>Dickerson Stab. Class had Given<br>Relation to Dulles Stab. Class |                    |                     |
|------------------------------|---|--|--------------------|---------------------|
|                              |   | Less Than<br>Dulles  | Equal to<br>Dulles | More Than<br>Dulles |
| 1                            | 1   | *  | 0                  | 100                 |
| 2                            | 12  | 22   | 17                 | 61                  |
| 3                            | 16  | 16   | 16                 | 68                  |
| 4                            | 48  | 14   | 27                 | 59                  |
| 5                            | 10  | 35   | 15                 | 50                  |
| 6                            | 10  | 47   | 53                 | *                   |
| 7                            | 3   | 100  | *                  | *                   |

\*The algorithm used for computing Dickerson Tower stability class had no provision for stability classes less than 1 nor greater than 6.

TABLE 5-2d

COMPARISON OF DULLES AND DICKERSON STABILITY CLASSES -  
TIME DISTRIBUTION OF DICKERSON CLASSES (UPPER LEVEL)

(Based on Upper Level Winds for 197 Hours in June, 1973)

| Dulles<br>Stability<br>Class | % of<br>Total<br>Hours<br>Having<br>Dulles<br>Stab. Class | Average # of Minutes out of<br>Each 30-Min. Period for which<br>Dickerson Stab. Class had given<br>Relation to Dulles Stab. Class |                    |                     |
|------------------------------|---|---|--------------------|---------------------|
|                              |   | Less Than<br>Dulles   | Equal to<br>Dulles | More Than<br>Dulles |
| 1                            | 1   | *   | 3                  | 27                  |
| 2                            | 12  | 8   | 3                  | 19                  |
| 3                            | 16  | 4   | 6                  | 20                  |
| 4                            | 48  | 4   | 8                  | 18                  |
| 5                            | 10  | 10  | 7                  | 13                  |
| 6                            | 10  | 14  | 16                 | *                   |
| 7                            | 3   | 30  | *                  | *                   |

\*The algorithm used for computing Dickerson Tower stability class had no provision for stability classes less than 1 nor greater than 6.

Overall bias was measured by computing the geometric mean deviation of all the points from the observed-predicted line (see Figure 5-5a). This is expressed as the % overall bias.

In addition, the % of total number of points falling within various regions of bias (both underpredicting and overpredicting) were computed. These are indicated by the diagonal bands in Figure 5-5b. This measure gives the overall distribution and range of predictive bias.

To evaluate the dispersion model's accuracy in specific regions, two measures of regional model accuracy were used. The first, called the predictive accuracy, is calculated as shown in Figure 5-5c. A series of windows is established along the predicted (horizontal) axis, and in each window the geometric mean deviation from the observed-predicted line is calculated and expressed as the mean % bias for that window. The predictive accuracy then consists of a series of numbers, one for each window, which ideally should all be 0%.

The second accuracy measure is called the frequency accuracy. As shown in Figure 5-5d, it is calculated by considering a series of concentration levels  $C_i$ , and for each  $C_i$ , the number of predictions above  $C_i$  are compared with the number of observations above  $C_i$  and is expressed as the percentage difference. The frequency accuracy then consists of a series of numbers, one for each  $C_i$ , which should all be 0%.

These two tests provide a means of focusing attention on any portion of the predicted-observed distribution. Whereas predictive accuracy provides specific information about narrow windows and directly indicates the percentage correction needed in those windows, the frequency accuracy is set up in exactly the same way that APL presents its predictions (as frequencies of exceeding levels). Also, note that when all predicted-observed points are along the predicted-observed line, all predictive and frequency accuracies are 0%, but that it is impossible for any other finite set of points to give 0% for all windows and levels for both tests.

Table 5-3a shows the results of the measures of overall bias, and Table 5-3b those of the specific predictive and frequency accuracy tests at the 50, 75, and 100 ppb levels (window width = 50 ppb); tabulated are the test results for

| 5 MIN<br>TUNING<br>FACTOR | OVERALL<br>BIAS<br>(%) | % OF CASES FALLING WITHIN GIVEN REGIONS OF BIAS |     |     |       |     |               |      |  |  |   |
|---------------------------|------------------------|---|-----|-----|-------|-----|---------------|------|--|--|---|
|                           |                        | ← UNDERPREDICT                                  |     |     |       |     | OVERPREDICT → |      |  |  |   |
|                           |                        | -X10  | -X5 | -X2 | EXACT | +X2 | +X5           | +X10 |  |  |   |
| None                      | +53                    | 0   | 0   | 6   | 24    | 33  | 29            | 8    |  |  | 0 |
| 0.95                      | +45                    | 0   | 0   | 6   | 26    | 34  | 27            | 7    |  |  | 0 |
| 0.90                      | +38                    | 0   | 0   | 9   | 26    | 34  | 25            | 6    |  |  | 0 |
| 0.85                      | +30                    | 0   | 0   | 9   | 28    | 34  | 23            | 6    |  |  | 0 |
| 0.80                      | +22                    | 0   | 0   | 13  | 28    | 31  | 22            | 6    |  |  | 0 |
| 0.75                      | +15                    | 0   | 0   | 15  | 30    | 31  | 19            | 5    |  |  | 0 |
| 0.70                      | + 7                    | 0   | 0   | 17  | 32    | 30  | 19            | 2    |  |  | 0 |
| 0.65                      | - 1                    | 0   | 1   | 22  | 31    | 26  | 18            | 2    |  |  | 0 |
| 0.60                      | - 8                    | 0   | 1   | 23  | 35    | 24  | 15            | 2    |  |  | 0 |

TABLE 5-3a: TUNING FACTORS FOR 5-MINUTE AVERAGE GLC  
- BIAS OF PREDICTIONS  
(BASED ON 128 TUNING POINTS)

| 5 MIN<br>TUNING<br>FACTOR | 50 PPB LEVEL                  |                              | 75 PPB LEVEL                  |                              | 100 PPB LEVEL                 |                              |
|---------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|-------------------------------|------------------------------|
|                           | PREDICTIVE<br>ACCURACY<br>(%) | FREQUENCY<br>ACCURACY<br>(%) | PREDICTIVE<br>ACCURACY<br>(%) | FREQUENCY<br>ACCURACY<br>(%) | PREDICTIVE<br>ACCURACY<br>(%) | FREQUENCY<br>ACCURACY<br>(%) |
| None                      | +62                           | +61                          | +59                           | +51                          | +79                           | +40                          |
| 0.95                      | +58                           | +60                          | +57                           | +36                          | +51                           | +30                          |
| 0.90                      | +53                           | +55                          | +42                           | +31                          | +39                           | +23                          |
| 0.85                      | +55                           | +47                          | +35                           | +16                          | +23                           | + 7                          |
| 0.80                      | +41                           | +39                          | +23                           | + 4                          | +13                           | -20                          |
| 0.75                      | +25                           | +26                          | +18                           | - 7                          | +13                           | -47                          |
| 0.70                      | +20                           | +13                          | +16                           | -13                          | - 1                           | -87                          |
| 0.65                      | + 9                           | + 6                          | + 6                           | -22                          | - 7                           | -97                          |
| 0.60                      | - 2                           | - 5                          | - 6                           | -47                          | -18                           | -97                          |

TABLE 5-3b: TUNING FACTORS FOR 5-MINUTE AVERAGE GLC  
- PREDICTIVE ACCURACY AND FREQUENCY ACCURACY  
(BASED ON 128 TUNING POINTS; WINDOW WIDTH = 50 PPB)

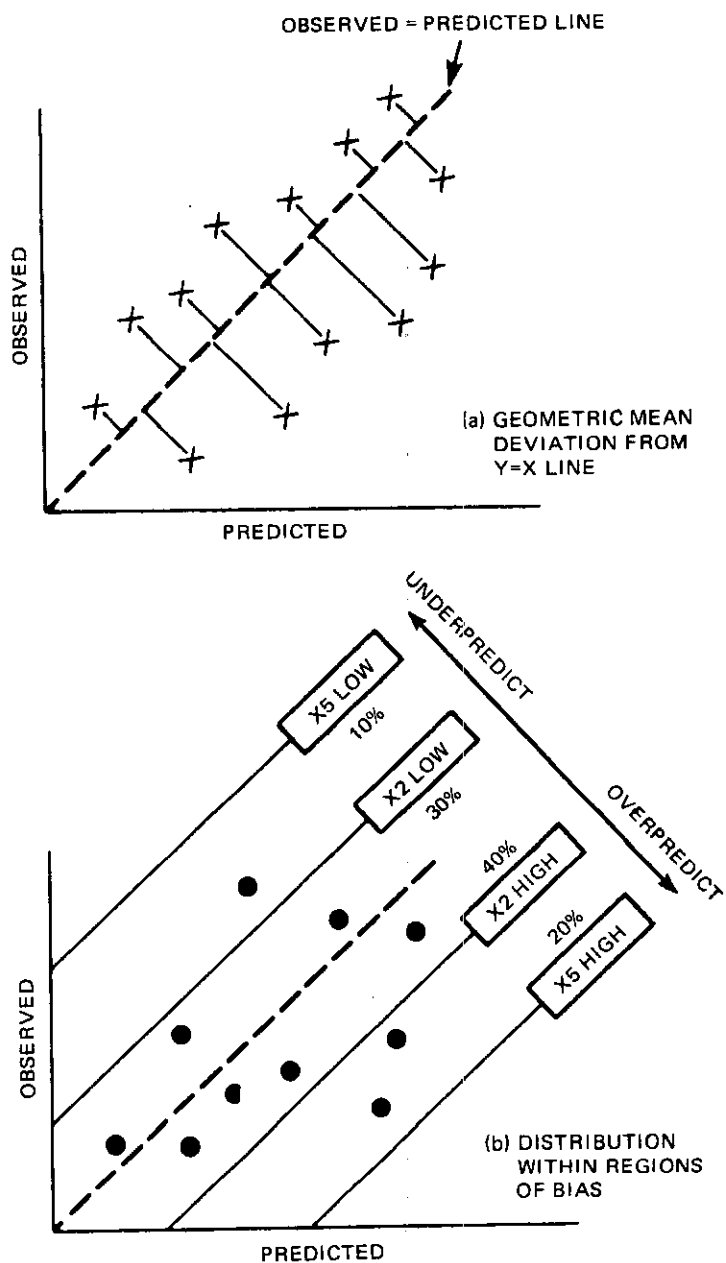


Fig. 5-5a, b: MEASURES OF OVERALL BIAS

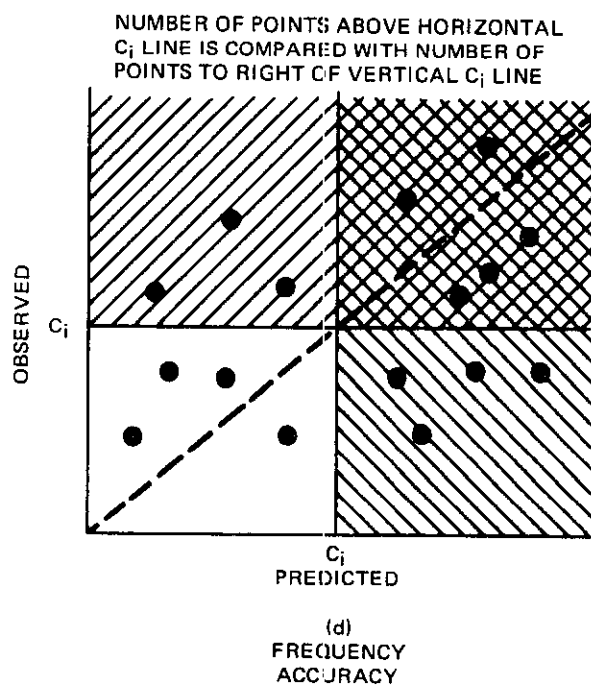
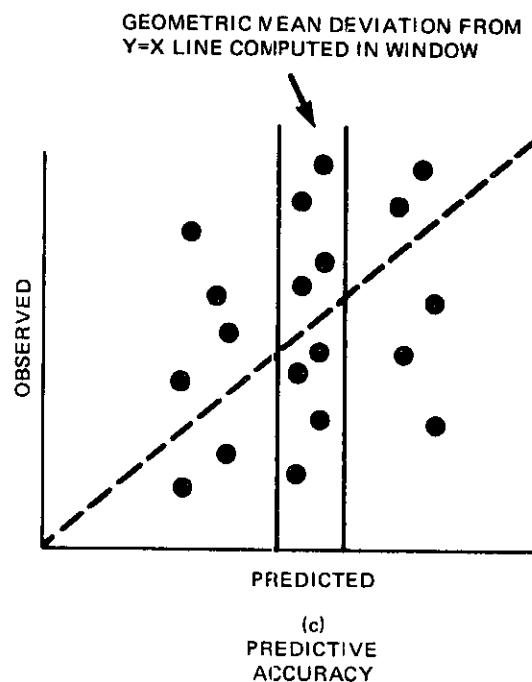


Fig. 5-5c, d: CALCULATION OF PREDICTIVE AND FREQUENCY  
ACCURACIES FOR MEASURING ACCURACY IN  
SPECIFIC REGIONS

the original observed-predicted distribution and also with the predicted values uniformly multiplied by various factors. Such a multiplication moves all data points horizontally the same distance on a log-log plot. As can be seen from Tables 5-3a and 5-3b, a factor of 0.8: 1) reduces the overprediction in the overall distribution while maintaining an overall safety margin of +20% overprediction; 2) reduces the overprediction in the 50 ppb region while maintaining a 50 ppb regional safety margin of +40% overprediction; and 3) more evenly distributes the points within bias bands while maintaining a distribution skewed toward overprediction. Figure 5-3 shows the distribution without the tuning factor, and Figure 5-4 shows the result of applying the 0.8 tuning factor.

#### Determination of 1-hour average GLC's

Turner's Method. During APL's model tuning, the mobile SO<sub>2</sub> monitoring van followed the plume's peak as the plume meandered back and forth. The traverses so obtained were used to compute the 5-minute average GLC. For the 1-hour GLC, a receptor is assumed to be fixed while the plume meanders across it for 1 hour. Because this receptor does not follow the plume's peak, the 1-hour GLC will generally be smaller than the average of the separate 5-minute readings obtained by following the peaks. To account for this effect, a multiplicative factor is usually applied to 5-minute average GLC's to convert them to 1-hour average GLC's. Turner (Ref. 5-4) gives the following formula:

$$T_2 \text{ minute average GLC} = (T_1 \text{ minute average GLC}) \left[ \frac{T_1}{T_2} \right]^P$$

where P is in the range 0.17 to 0.20. The multiplicative factors for converting 5-, 10-, and 15 minute average GLC's to 1-hour GLC's as derived from Turner's formula are given in Table 5-4. A factor of 0.75 would be a conservative conversion factor from 5-minute GLC's to 1-hour GLC's, and if it were applied, the proposed Dicerkson plant would meet the administrative guideline that 50 ppb hourly average not be exceeded more than once per month.

| Source               | Multiplicative Factor<br>to Convert Given Time<br>Average to 1-Hour Average |            |            |
|----------------------|---|------------|------------|
|                      | 5 Minutes   | 10 Minutes | 15 Minutes |
| Turner's<br>Workbook | 0.61-0.66   | 0.70-0.74  | 0.76-0.79  |

TABLE 5-4: Comparison of Averaging Time Conversion Factors

Wind Persistence Method. As an alternate approach, wind data taken at Dickerson was analyzed to determine directly the frequency with which 5-minute averages transferred to 1-hour averages at various reference levels. The study considered the role of short-term wind variations (less than one hour) in producing averaging over an hour.

To simulate the short-term averaging mechanism, a computer program was written to move a Gaussian-shaped plume back and forth according to lower level winds. The winds used by the model were 10-minute-average winds from the lower level of the Dickerson tower. The winds were taken in groups of six consecutive 10-minute values to compose one hour's variation; the computer moved the plume accordingly across a fixed receptor and mathematically averaged the concentration over one hour. The average obtained was then the transition factor from 5-minute GLC's to 1-hour GLC's.

The above program was run for 2,160 10-minute average winds during the month of June 1973, and resulted in a probability distribution of transition factors (see Table 5-5). This distribution is used to determine the probability that a given 5-minute GLC will persist long enough to exceed a given 1-hour GLC. For instance, to determine the probability that a 5-minute GLC of 59 ppb will persist to produce a 1-hour GLC in excess of 50 ppb, we find the probability that the transition factor will be greater than:

$$50/59 = 0.85$$

since all transition factors greater than 0.85 will convert the 59 ppb 5-minute GLC to a 1-hour GLC greater than 50 ppb; from Table 5-5, we see that the probability is 0.30. We can thus calculate the probabilities that various 5-minute GLC's will exceed given 1-hour GLC's of interest; and this has been done in Table 5-5.

TABLE 5-5

PROBABILITY DISTRIBUTION OF 5-MINUTE TO 1-HOUR WIND  
PERSISTENCE CONVERSION FACTORS FOR DICKERSON  
(BASED ON 2,160\* 10-MINUTE AVERAGE 10 M WINDS FROM DICKERSON TOWER)

| Wind<br>Persistence<br>5-Minute to<br>1-Hour<br>Conversion<br>Factor | 5-Minute GLC (PPB)<br>Necessary to Exceed<br>Given 1-Hour GLC Ref Level<br>for Each Conversion Factor |    |     |     | Probability<br>of<br>Equal or<br>Greater<br>Conversion<br>Factor |
|--|---|----|-----|-----|--|
|  | 1 Hour Reference Levels (PPB)   |    |     |     |  |
|  | 50  | 55 | 60  | 65  |  |
| 1.0  | 50  | 55 | 60  | 65  | 0.02   |
| 0.95   | 53  | 58 | 63  | 68  | 0.10   |
| 0.90   | 56  | 61 | 67  | 72  | 0.18   |
| 0.85   | 59  | 65 | 71  | 76  | 0.30   |
| 0.80   | 62  | 69 | 75  | 81  | 0.36   |
| 0.75   | 67  | 73 | 80  | 87  | 0.42   |
| 0.70   | 71  | 79 | 86  | 93  | 0.49   |
| 0.65   | 77  | 85 | 92  | 100 | 0.54   |
| 0.60   | 83  | 92 | 100 | 108 | 0.60   |

\*This represents 15 days from 6 months of available data;  
processing of remainder of data is in progress.

To determine the total number of 5-minute average levels persisting to become 1-hour averages  $\geq 50$  ppb (or any other desired comparison level), it is necessary to determine and sum the probabilities that each predicted 5-minute GLC in excess of 50 ppb (or other reference level) will be converted to 1-hour levels in excess of 50 ppb. The higher the 5-minute GLC, the greater the probability of its exceeding 50 ppb. The configurations which have been considered for Dickerson are described in a subsequent section of this chapter; however, three of these cases are given in Table 5-6. These results are slightly more conservative than the predictions using Turner's method. They indicate that, at Dickerson, the administrative guideline is not quite achieved, although for two of the configurations, 55 ppb is exceeded only once per month. It should be noted that:

1. These calculations apply to the total Dickerson complex including the existing plant and both 850 MWe proposed additions.
2. Full-load operation is assumed at all times.

#### Long-Term Wind Persistence

To study the long-term persistence pattern at Dickerson, a persistence table was constructed from the hourly-averaged Dickerson lower level tower winds for the months of June and July 1973, and is given in Table 5-7. The predominant wind direction is in the S-SW sector, but at least 2/3 of winds in all sectors persist for no more than 3 hours and 85% for no more than six hours. From this study, it seems most likely for long-term persistence to develop in the S and NW quadrants, the former including winds blowing toward the Sugarloaf Mountain area.

TABLE 5-6  
FREQUENCIES OF EXCEEDING VARIOUS LEVELS FOR 1-HOUR  
GLC BASED ON DICKERSON WIND PERSISTENCE STUDIES

| CONFIGURATION     | # HOURS/MONTH GIVEN LEVEL<br>IS EXCEEDED FOR 1 HOUR GLC |           |           |           |
|-------------------|---|-----------|-----------|-----------|
|                   | 50<br>PPB   | 55<br>PPB | 60<br>PPB | 65<br>PPB |
| DE 1 STACK: 850'  | 1.6   | 0.89      | 0.43      | 0.26      |
| DP 1 STACK: 850'  |   |           |           |           |
| DE 2 STACKS: 400' | 2.0   | 1.0       | 0.45      | 0.26      |
| DP 1 STACK: 850'  |   |           |           |           |
| DE 1 STACK: 750'  | 2.4   | 1.5       | 1.2       | 0.72      |
| DP 1 STACK: 750'  |   |           |           |           |

DE = Dickerson existing plant.

DP = Dickerson proposed (2 - 850 MWE units).

Exit temperature taken to be  $\approx 125^{\circ}\text{F}$ .

TABLE 5-7  
LONG-TERM WIND PERSISTENCE  
(Based on Lower Level Tower Winds for June and July 1973)

| Persistence<br>(Hours)                 | % of Winds Which Persisted in Given 45° Sector for Specified Periods |      |      |      |      |      |      |      |
|--|--|------|------|------|------|------|------|------|
|  | N-NE   | NE-E | E-SE | SE-S | S-SW | SW-W | W-NW | NW-N |
| 1                                      | 41   | 77   | 66   | 41   | 43   | 70   | 54   | 52   |
| 2-3                                    | 26   | 23   | 21   | 31   | 28   | 20   | 31   | 16   |
| 4-6                                    | 33   |      | 10   | 15   | 19   | 7    | 3    | 16   |
| 7-9                                    |  |      | 3    | 8    | 2    | 3    | 3    | 5    |
| 10-12                                  |  |      |      | 5    | 2    |      | 6    | 8    |
| 13-15                                  |  |      |      |      | 4    |      | 3    | 3    |
| 16 Over                                |  |      |      |      | 2    |      |      |      |
| % Time Wind<br>Blew in<br>Given Sector | 9  | 4    | 10   | 16   | 25   | 7    | 12   | 17   |

### Analytic Results

Estimated SO<sub>2</sub> Levels. The methods described in the April 1973 Dickerson Report (Ref. 5-2) as improved with the fine tuning and averaging techniques described here have been applied to the present Dickerson Power Plant and its proposed expansion. The presence of scrubbers of 90% removal effectiveness for SO<sub>2</sub> and the use of 2% sulphur coal has been assumed. All other conditions as given in Ref. 5-2 relative to emission characteristics apply and are summarized in Table 5-8 which is reproduced directly from the earlier report.

In this study, nine (9) stack (and plant) configurations were investigated. These are listed and described in Table 5-9. Tables 5-10a through 5-10h give the frequencies of equalling or exceeding certain percentages of the 5-minute, 1-hour, 24-hour, and 1-year standards in an area having a 20-mile radius around the power plant for the configurations given in Table 5-9. These tables are simplified versions of the charts given in the first Dickerson Report (Ref. 5-2) in that they do not indicate the values obtained in various sub-regions of the total area. This simplification is based on the fact that the impact is quite low over the entire region. These tables also show the maximum GLC predicted within the area for the configuration shown.

The geographical distribution of the annual average concentration of SO<sub>2</sub> is given in Figure 5-6. The dashed lines are annual average isopleth of SO<sub>2</sub> for the configuration in which both existing and proposed additions utilize 850-foot stacks. The maximum annual average observed is less than 10% of the value allowed by Maryland Standards.

The most critical standard to be met is the 1-hour averaged GLC standard. Table 5-11 summarizes the number of hours/month that any of the configurations studied would exceed 50 ppb, 55 ppb, 60 ppb, etc. This table shows quite clearly that the State's administrative guideline (i.e., no single emitter producing in excess of 50% of the standard) is met for all configurations with only one 850 MWe unit added, and that it is very nearly met for the full expansion proposed. It is also clear that the full proposed plant expansion will not cause levels in excess of those permitted by Maryland Standards for SO<sub>2</sub> when 90% scrubbing and 2% coal are used.

It is concluded from this work that it is advisable to require that all emissions from the plant be from 850-foot stacks. Even though the above predictions show that 400-foot stacks produce similar 1-hour GLC's, considerations of scrubber reliability indicate that the 850-foot stacks offer greater margin for reliability failure.

Estimated NO<sub>2</sub> Levels. Using the methods of Reference 5-1, the annual average levels of NO<sub>2</sub> are everywhere less than 1.38 ppb. The maximum level is less than 2.76% of the standard and the average value over the region would equal less than 1% of the standard.

| UNIT  | Coal<br>Sulfur<br>Content<br>(%) | Power<br>Rating<br>(MW) | Mass<br>Flow Rate<br>(Kg/Sec) | Exit<br>Temp.<br>(°C) | Stack<br>Height<br>(M) | SO <sub>2</sub> **<br>Emission<br>(Kg/Sec) | Gaseous<br>Fluoride<br>Emission<br>(Kg/Sec) | Particulate<br>**<br>Emission<br>(Kg/Sec) | NO <sub>x</sub><br>Emission<br>(Kg/Sec) |
|-------|----------------------------------|-------------------------|-------------------------------|-----------------------|------------------------|--|---|---|---|
| 1 + 2 | 2                                | 370                     | 378                           | 52                    | 122                    | 0.1196                                     | 0.00079                                     | 0.010                                     | 0.31                                    |
| 3     | 2                                | 185                     | 189                           | 52                    | 122                    | 0.0608                                     | 0.00040                                     | 0.0052                                    | 0.16                                    |
| 4     | 2                                | 850                     | 998                           | 54                    | 305                    | 0.318                                      | 0.0021                                      | 0.079                                     | 0.83                                    |
| 5     | 2                                | 850                     | 998                           | 54                    | 305                    | 0.318                                      | 0.0021                                      | 0.079                                     | 0.83                                    |
| 1 + 2 | 1 *                              |                         |                               |                       |                        | 0.0595                                     |   |   |   |
| 3     | 1 *                              |                         |                               |                       |                        | 0.0304                                     |   |   |   |
| 4     | 1 *                              |                         |                               |                       |                        | 0.159                                      |   |   |   |
| 5     | 1 *                              |                         |                               |                       |                        | 0.159                                      |   |   |   |
| 1 + 2 | 3 *                              |                         |                               |                       |                        | 0.1785                                     |   |   |   |
| 3     | 3 *                              |                         |                               |                       |                        | 0.0912                                     |   |   |   |
| 4     | 3 *                              |                         |                               |                       |                        | 0.477                                      |   |   |   |
| 5     | 3 *                              |                         |                               |                       |                        | 0.477                                      |   |   |   |

\* Other parameters assumed to remain the same after change in sulfur content of coal.  
\*\* Assumes scrubber and precipitators to give 90% SO<sub>2</sub> removal, 50% gaseous fluoride removal, and greater than 99% particulate removal.

TABLE 5-8. FULL LOAD POWER PLANT DESIGN AND OPERATING CHARACTERISTICS  
(Taken from RRI)

| NUMBER | DICKERSON EXISTING |          |                       | DICKERSON PROPOSED |         |                       |
|--------|--------------------|----------|-----------------------|--------------------|---------|-----------------------|
|        | UNITS              | # STACKS | STACK HT<br>EXIT TEMP | UNITS              | #STACKS | STACK HT<br>EXIT TEMP |
| 1      | 1,2,3              | 1        | 850' / 125°F          | 4                  | 1       | 850' / 125°F          |
| 2      | 1,2,3              | 2        | 400' / 125°F          | 4                  | 1       | 850' / 125°F          |
| 3      | 1,2,3              | 1        | 850' / 125°F          | 4,5                | 1       | 850' / 125°F          |
| 4      | 1,2,3              | 2        | 400' / 125°F          | 4,5                | 1       | 850' / 125°F          |
| 5      | 1,2,3              | 1        | 750' / 125°F          | 4,5                | 1       | 750' / 125°F          |
| 6      | 1,2,3              | 2        | 400' / 125°F          | -                  | -       | -                     |
| 7      | 1,2,3              | 1        | 850' / 125°F          | -                  | -       | -                     |
| 8      | -                  | -        | -                     | 4                  | 1       | 850' / 125°F          |
| 9      | -                  | -        | -                     | 4,5                | 1       | 850' / 125°F          |

TABLE 5-9. SUMMARY OF CONFIGURATIONS STUDIED.

Table 5-10a. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

5 Minutes

- Pasquill-Turner dispersion model and Briggs' plume rise used.

- Assumptions: 2% sulfur coal, 90% scrubbing

- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.

- DE = Dickerson Existing, DP = Dickerson Proposed.

Area

20 Mile Radius

| # Units                 | # of Stacks | St Ht/Exit Temperature   | Max (ppb)        | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |    |   | % Frequency of exceeding anywhere within Area, these %'s of standard: |    |    |    |   |
|-------------------------|-------------|--------------------------|------------------|---|----|----|----|---|---|----|----|----|---|
|                         |             |                          |                  | 100   | 75 | 50 | 10 | 1 | 100   | 75 | 50 | 10 | 1 |
| 1. DE #1,2,3<br>DP #4   | 1<br>1      | 850'/125°F<br>850'/125°F | 44<br>1 mi, 110° | 0.20 6.3  |    |    |    |   | 1.3 42.   |    |    |    |   |
| 2. DE #1,2,3<br>DP #4   | 2<br>1      | 400'/125°F<br>850'/125°F | 50<br>1 mi, 230° | 0.51 8.7  |    |    |    |   | 10. 44.   |    |    |    |   |
| 3. DE #1,2,3<br>DP #4,5 | 1<br>1      | 850'/125°F<br>850'/125°F | 81<br>1 mi, 110° | 0.41 6.3  |    |    |    |   | 4.7 42.   |    |    |    |   |
| 4. DE #1,2,3<br>DP #4,5 | 2<br>1      | 400'/125°F<br>850'/125°F | 81<br>1 mi, 110° | 0.71 8.2  |    |    |    |   | 12. 44.   |    |    |    |   |
| 5. DE #1,2,3<br>DP #4,5 | 1<br>1      | 750'/125°F<br>750'/125°F | 84<br>1 mi, 110° | 0.41 6.6  |    |    |    |   | 5.5 42.   |    |    |    |   |
|                         |             |                          |                  |   |    |    |    |   |   |    |    |    |   |
|                         |             |                          |                  |   |    |    |    |   |   |    |    |    |   |
|                         |             |                          |                  |   |    |    |    |   |   |    |    |    |   |

Table 5- 10b. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

5 Minutes

- Pasquill-Turner dispersion model and Briggs's plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE = Dickerson Existing, DP = Dickerson Proposed

Area

20 Mile Radius

| # Units      | # of Stacks | St Ht/Exit Temperature | Max (ppb)        | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |      |     | % Frequency of exceeding anywhere within Area, these %'s of standard: |    |    |      |     |
|--------------|-------------|------------------------|------------------|---|----|----|------|-----|---|----|----|------|-----|
|              |             |                        |                  | 100   | 75 | 50 | 10   | 1   | 100   | 75 | 50 | 10   | 1   |
| 6. DE #1,2,3 | 2           | 400'/125°F             | 45<br>1 mi, 10°  |   |    |    | 0.51 | 6.9 |   |    |    | 7.6  | 44. |
| 7. DE #1,2,3 | 1           | 850'/125°F             | 22<br>1 mi, 160° |   |    |    |      | 3.2 |   |    |    |      | 40. |
| 8. DP #4     | 1           | 850'/125°F             | 44<br>1 mi, 110° |   |    |    | 0.20 | 3.7 |   |    |    | 0.92 | 40. |
| 9. DP #4,5   | 1           | 850'/125°F             | 81<br>1 mi, 110° |   |    |    | 0.40 | 4.6 |   |    |    | 3.5  | 40. |
|              |             |                        |                  |   |    |    |      |     |   |    |    |      |     |
|              |             |                        |                  |   |    |    |      |     |   |    |    |      |     |
|              |             |                        |                  |   |    |    |      |     |   |    |    |      |     |
|              |             |                        |                  |   |    |    |      |     |   |    |    |      |     |

Table 5-10c. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

1 Hour

- Pasquill-Turner dispersion model and Brigg's plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing.
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE = Dickerson Existing, DP = Dickerson Proposed.
- # of hours/month = 7.2 x (% Frequency from Table).

Area

20 Mile Radius

| # Units                 | # of Stacks | St Ht/Exit Temperature   | Max (ppb)        | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |      |      |     | % Frequency of exceeding, anywhere within Area, these %'s of standard: |      |     |     |     |
|-------------------------|-------------|--------------------------|------------------|---|----|------|------|-----|--|------|-----|-----|-----|
|                         |             |                          |                  | 100   | 75 | 50   | 10   | 1   | 100  | 75   | 50  | 10  | 1   |
| 1. DE #1,2,3<br>DP #4   | 1<br>1      | 850'/125°F<br>850'/125°F | 33<br>1 mi, 110° |   |    |      | 0.51 | 7.0 |  |      |     | 9.7 | 42. |
| 2. DE #1,2,3<br>DP #4   | 2<br>1      | 400'/125°F<br>850'/125°F | 38<br>1 mi, 230° |   |    |      | 2.9  | 9.1 |  |      |     | 39. | 44. |
| 3. DE #1,2,3<br>DP #4,5 | 1<br>1      | 850'/125°F<br>850'/125°F | 61<br>1 mi, 110° |   |    | 0.10 | 1.1  | 7.0 |  | 0.22 | 21. | 42. |     |
| 4. DE #1,2,3<br>DP #4,5 | 2<br>1      | 400'/125°F<br>850'/125°F | 61<br>1 mi, 110° |   |    | 0.10 | 3.1  | 9.3 |  | 0.28 | 39. | 44. |     |
| 5. DE #1,2,3<br>DP #4,5 | 1<br>1      | 750'/125°F<br>750'/125°F | 63<br>1 mi, 110° |   |    | 0.10 | 1.5  | 8.0 |  | 0.33 | 28. | 43. |     |
|                         |             |                          |                  |   |    |      |      |     |  |      |     |     |     |
|                         |             |                          |                  |   |    |      |      |     |  |      |     |     |     |
|                         |             |                          |                  |   |    |      |      |     |  |      |     |     |     |

Table 5-10d. Frequencies of Exceeding Specified SO<sub>2</sub> Ground-Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

1 Hour

- Pasquill-Turner dispersion model and Briggs' plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing.
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE = Dickerson Existing, DP = Dickerson Proposed.
- # of hours/month = 7.2 x (% Frequency from Table).

Area

20 Mile Radius

| # Units      | # of Stacks | St Ht./Exit Temperature | Max (ppb)        | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |      |      | % Frequency of exceeding anywhere within Area, these %'s of standard: |    |      |     |     |
|--------------|-------------|-------------------------|------------------|---|----|----|------|------|---|----|------|-----|-----|
|              |             |                         |                  | 100   | 75 | 50 | 10   | 1    | 100   | 75 | 50   | 10  | 1   |
| 6. DE #1,2,3 | 2           | 400'/125°F              | 34<br>1 mi, 10°  |   |    |    | 2.6  | 7.1  |   |    |      | 37. | 44. |
| 7. DE #1,2,3 | 1           | 850'/125°F              | 17<br>1 mi, 160° |   |    |    | 0.20 | 3.3  |   |    |      | 1.1 | 42. |
| 8. DP #4     | 1           | 850'/125°F              | 33<br>1 mi, 110° |   |    |    | 0.41 | 4.8  |   |    |      | 4.6 | 41. |
| 9. DP #4,5   | 1           | 850'/125°F              | 61<br>1 mi, 110° |   |    |    | 0.10 | 0.92 | 5.7   |    | 0.22 | 13. | 41. |
|              |             |                         |                  |   |    |    |      |      |   |    |      |     |     |
|              |             |                         |                  |   |    |    |      |      |   |    |      |     |     |
|              |             |                         |                  |   |    |    |      |      |   |    |      |     |     |
|              |             |                         |                  |   |    |    |      |      |   |    |      |     |     |

Table 5-10e. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

24 Hours

- Pasquill-Turner dispersion model and Briggs' plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE = Dickerson Existing, DP = Dickerson Proposed.
- # days/month = 0.30 x (% Frequency from Table).

Area

20 Mile Radius

| # Units                 | # of Stacks | St Ht/Exit Temperature   | Max (ppb)         | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |    |   | % Frequency of exceeding, anywhere within Area, these %'s of standard: |    |    |    |   |
|-------------------------|-------------|--------------------------|-------------------|---|----|----|----|---|--|----|----|----|---|
|                         |             |                          |                   | 100   | 75 | 50 | 10 | 1 | 100  | 75 | 50 | 10 | 1 |
| 1. DE #1,2,3<br>DP #4   | 1<br>1      | 850'/125°F<br>850'/125°F | 6.9<br>1 mi, 110° | 0.82 23.  |    |    |    |   | 0.82 100.  |    |    |    |   |
| 2. DE #1,2,3<br>DP #4   | 2<br>1      | 400'/125°F<br>850'/125°F | 8.3<br>2 mi, 280° | 2.5 31.   |    |    |    |   | 16. 100.   |    |    |    |   |
| 3. DE #1,2,3<br>DP #4,5 | 1<br>1      | 850'/125°F<br>850'/125°F | 12<br>1 mi, 110°  | 1.6 22.   |    |    |    |   | 7.4 100.   |    |    |    |   |
| 4. DE #1,2,3<br>DP #4,5 | 2<br>1      | 400'/125°F<br>850'/125°F | 13<br>1 mi, 110°  | 3.3 31.   |    |    |    |   | 23. 100.   |    |    |    |   |
| 5. DE #1,2,3<br>DP #4,5 | 1<br>1      | 750'/125°F<br>750'/125°F | 13<br>1 mi, 110°  | 2.5 25.   |    |    |    |   | 12. 100.   |    |    |    |   |
|                         |             |                          |                   |   |    |    |    |   |  |    |    |    |   |
|                         |             |                          |                   |   |    |    |    |   |  |    |    |    |   |
|                         |             |                          |                   |   |    |    |    |   |  |    |    |    |   |

Table 5-10f. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

24 Hours

- Pasquill-Turner dispersion model and Briggs's plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE = Dickerson Existing, DP = Dickerson Proposed.
- # days/month = 0.30 x (% Frequency from Table.

Area

20 Mile Radius

| # Units      | # of Stacks | St Ht/Exit Temperature | Max (ppb)         | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |    |   | % Frequency of exceeding, anywhere within Area, these %'s of standard: |    |    |    |   |
|--------------|-------------|------------------------|-------------------|---|----|----|----|---|--|----|----|----|---|
|              |             |                        |                   | 100   | 75 | 50 | 10 | 1 | 100  | 75 | 50 | 10 | 1 |
| 6. DE #1,2,3 | 2           | 400'/125°F             | 7.7<br>1 mi, 130° | 2.5 25.   |    |    |    |   | 9.8 98.  |    |    |    |   |
| 7. DE #1,2,3 | 1           | 850'/125°F             | 2.3<br>3 mi, 160° | 15.   |    |    |    |   | 93.  |    |    |    |   |
| 8. DP #4     | 1           | 850'/125°F             | 6.2<br>1 mi, 110° | 0.82 16.  |    |    |    |   | 0.82 99.   |    |    |    |   |
| 9. DP #4,5   | 1           | 850'/125°F             | 11<br>1 mi, 110°  | 0.82 17.  |    |    |    |   | 4.9 100.   |    |    |    |   |
|              |             |                        |                   |   |    |    |    |   |  |    |    |    |   |
|              |             |                        |                   |   |    |    |    |   |  |    |    |    |   |
|              |             |                        |                   |   |    |    |    |   |  |    |    |    |   |
|              |             |                        |                   |   |    |    |    |   |  |    |    |    |   |

Table 5-10g. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

1 Year

- Pasquill-Turner dispersion model and Briggs's plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE - Dickerson Existing, DP - Dickerson Proposed.

Area

20 Mile Radius

| # Units                 | # of Stacks | St Ht/Exit Temperature   | Max (ppb)          | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |    |      | % Frequency of exceeding, anywhere within Area, these %'s of standard: |    |    |    |      |
|-------------------------|-------------|--------------------------|--------------------|---|----|----|----|------|--|----|----|----|------|
|                         |             |                          |                    | 100   | 75 | 50 | 10 | 1    | 100  | 75 | 50 | 10 | 1    |
| 1. DE #1,2,3<br>DP #4   | 1<br>1      | 850'/125°F<br>850'/125°F | 0.31<br>3 mi, 150° |   |    |    |    | 100. |  |    |    |    | 100. |
| 2. DE #1,2,3<br>DP #4   | 2<br>1      | 400'/125°F<br>850'/125°F | 0.70<br>1 mi, 140° |   |    |    |    | 100. |  |    |    |    | 100. |
| 3. DE #1,2,3<br>DP #4,5 | 1<br>1      | 850'/125°F<br>850'/125°F | 0.38<br>3 mi, 150° |   |    |    |    | 100. |  |    |    |    | 100. |
| 4. DE #1,2,3<br>DP #4,5 | 2<br>1      | 400'/125°F<br>850'/125°F | 0.74<br>1 mi, 140° |   |    |    |    | 100. |  |    |    |    | 100. |
| 5. DE #1,2,3<br>DP #4,5 | 1<br>1      | 750'/125°F<br>750'/125°F | 0.46<br>3 mi, 150° |   |    |    |    | 100. |  |    |    |    | 100. |
|                         |             |                          |                    |   |    |    |    |      |  |    |    |    |      |
|                         |             |                          |                    |   |    |    |    |      |  |    |    |    |      |
|                         |             |                          |                    |   |    |    |    |      |  |    |    |    |      |

Table 5-10h. Frequencies of Exceeding Specified SO<sub>2</sub> Ground Level Concentrations Due to the Proposed and Existing Dickerson Power Plant

Averaging Time

1 Year

- Pasquill-Turner dispersion model and Brigg's plume rise used.
- Assumptions: 2% sulfur coal, 90% scrubbing
- Meteorological data from Dulles International Airport, 4 months of 1970, sampled at 3-hour intervals, total of 982 cases.
- DE - Dickerson Existing, DP - Dickerson Proposed.

Area

20 Mile Radius

| # Units      | # of Stacks | St Ht/Exit Temperature | Max (ppb)          | % Frequency at Point of Max Frequency of exceeding these %'s of standard: |    |    |    |      | % Frequency of exceeding, anywhere within Area, these %'s of standard: |    |    |    |      |
|--------------|-------------|------------------------|--------------------|---|----|----|----|------|--|----|----|----|------|
|              |             |                        |                    | 100   | 75 | 50 | 10 | 1    | 100  | 75 | 50 | 10 | 1    |
| 6. DE #1,2,3 | 2           | 400'/125°F             | 0.61<br>1 mi, 140° |   |    |    |    | 100. |  |    |    |    | 100. |
| 7. DE #1,2,3 | 1           | 850'/125°F             | 0.15<br>3 mi, 160° |   |    |    |    | 100. |  |    |    |    | 100. |
| 8. DP #4     | 1           | 850'/125°F             | 0.19<br>3 mi, 150° |   |    |    |    | 100. |  |    |    |    | 100. |
| 9. DP #4,5   | 1           | 850'/125°F             | 0.27<br>4 mi, 150° |   |    |    |    | 100. |  |    |    |    | 100. |
|              |             |                        |                    |   |    |    |    |      |  |    |    |    |      |
|              |             |                        |                    |   |    |    |    |      |  |    |    |    |      |
|              |             |                        |                    |   |    |    |    |      |  |    |    |    |      |
|              |             |                        |                    |   |    |    |    |      |  |    |    |    |      |

Table 5-11

SUMMARY OF NUMBER OF HOURS PER MONTH OF EXCEEDING ONE-HOUR  
GLC LEVELS ANYWHERE WITHIN 20-MILE RADIUS OF PLANT\*

| CONFIGURATION<br>NUMBER | # HOURS/MONTH GIVEN<br>1-HOUR GLC IS EXCEEDED |           |           |           |
|-------------------------|---|-----------|-----------|-----------|
|                         | 50<br>ppb                                     | 55<br>ppb | 60<br>ppb | 65<br>ppb |
| 1                       | 0   | 0         | 0         | 0         |
| 2                       | 0   | 0         | 0         | 0         |
| 3                       | 1.6   | 0.89      | 0.43      | 0.26      |
| 4                       | 2.0   | 1.0       | 0.45      | 0.26      |
| 5                       | 2.4   | 1.5       | 1.2       | 0.72      |
| 6                       | 0   | 0         | 0         | 0         |
| 7                       | 0   | 0         | 0         | 0         |
| 8                       | 0   | 0         | 0         | 0         |
| 9                       | 1.6   | 0.89      | 0.43      | 0.26      |

\* The 50 ppb entries shown above are consistent with those given in Tables 5-10c and d for exceeding 50% of the 1-hour standard (50% = 50 ppb) anywhere within the 20-mile radius area around the plant.

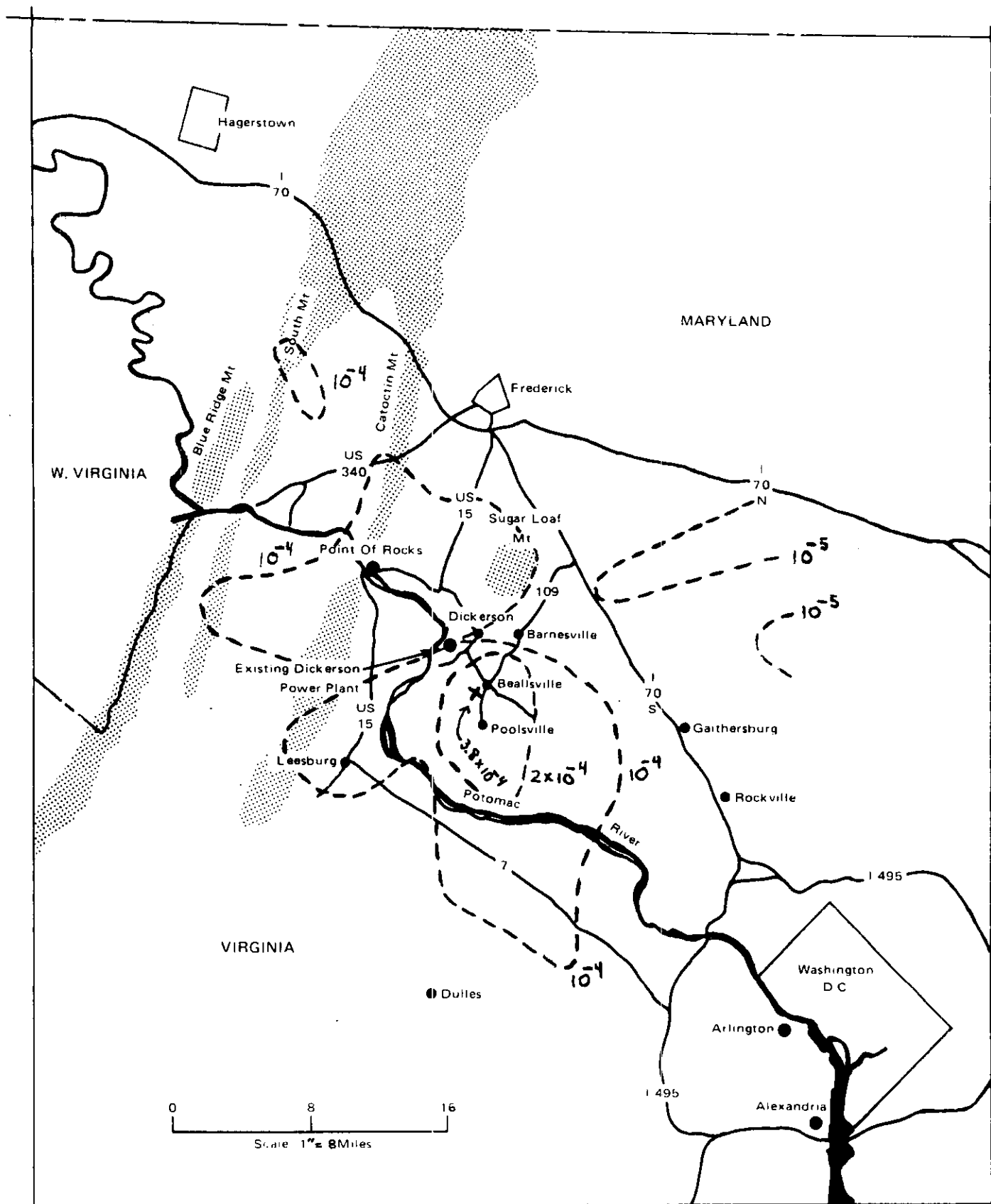


Fig. 5-6. ANNUAL AVERAGE GROUND-LEVEL CONCENTRATION ISOPLETHS FOR COMBINED DICKERSON EXISTING (#1, 2, 3: ONE 850-FOOT STACK) AND PROPOSED (#4, 5: ONE 850-FOOT STACK).

Concentrations in PPM  $\text{SO}_2$ .

## AIR CHEMISTRY

The effect of some effluents on the environment is more strongly determined by their chemical and physical properties. The four areas that will be discussed are emission of fluorides, particulates, oxidation of  $\text{SO}_2$  to sulfates, and acidification of rainfall around the plant. All of these processes will be affected by the presence of the  $\text{SO}_2$  scrubbing system necessary to bring predicted ambient  $\text{SO}_2$  levels within allowed Maryland standards. The effects of the scrubbers and of the electrostatic precipitators have been considered in each case. The scrubbing system explicitly assumed is the magnesium oxide system. However, any of the other wet scrubbing systems available, such as lime-limestone, or sodium sulfite-sodium bisulfite system, would probably have a very similar impact.

### Fluorides

Due to the toxic nature of fluorides to cattle, concern has been expressed about the amount of fluorides produced by a large coal-fired plant like Dickerson, since fluorides run on the average about .01 weight percent in coal (Ref. 5-5). Of this amount, about ten percent is retained in the plant as bottom ash (Ref. 5-6). The fluoride released from the coal will be almost exclusively gaseous HF at the temperatures in the firebox (Ref. 5-6). In the process of moving between the firebox and the scrubber, some HF may be converted to solid  $\text{CaF}_2$ . Particulate fluoride ( $\text{CaF}_2$ ) would be removed in the precipitators and the scrubbers. HF could also be removed by the scrubber. Chemical Construction Corporation (CHEMICO), the manufacturer of the 92.5 MWe prototype  $\text{SO}_2$  scrubber presently installed at Dickerson, estimates that 80% of the total fluorides reaching the scrubber will be removed (Ref. 5-7). This means that 0.022 pound of fluoride per ton of coal would be emitted. This corresponds to 0.00234 kg/sec. of fluoride from the present and proposed plants (five units) at full load. By scaling the fluoride emission to that of  $\text{SO}_2$ , we can obtain the maximum 24-hour concentration for comparison with the State standards.

To get the concentration of fluoride in ppb multiply the  $\text{SO}_2$  concentrations in ppb by

$$\left( \frac{2.34 \times 10^{-3}}{0.8164} \right) \cdot \frac{(64)}{(19)} = 9.69 \times 10^{-3} \text{ ppb}$$

This calculation assumes all fluorides disperse as a gas. The maximum 24-hour gaseous fluoride concentration for a plant configuration of two 850-foot stacks will be 0.117 ppb. This should be compared with a 24-hour standard of 2 ppb and a 72-hour standard of 0.5 ppb. The maximum annual average concentration is 0.0037 ppb. There is no State standard for annual average fluoride concentration.

The question has been raised of the additive effect of fluorides from Dickerson with those from the EASTALCO Aluminum Plant. EASTALCO is approximately six miles north of the Dickerson station. An examination of the 24-hour average gaseous fluoride data taken by the State Fluoride Monitoring Program (Ref. 5-8) shows no correlation between high values and wind coming from the direction of the present Dickerson plant. It should also be noted that the maximum 24-hour projected concentration calculated above is at a point one mile southeast of the Dickerson plant.

In addition, the State, at the request of the Public Service Commission, has set up a joint program with the Fluoride Monitoring Program, PEPCO and the State Power Plant Monitoring Group to check fluoride emissions from the Dickerson plant both now and in the future, along with those from EASTALCO.

### Particulates

Release of particulate material by the combustion of coal has long been recognized as a problem. To solve it, highly efficient electrostatic precipitators and wet scrubbers have been developed. In fact, these systems are necessary not only to prevent emission of particulates to the atmosphere, but also to prevent clogging of the SO<sub>2</sub> scrubbers. CHEMICO has estimated that 0.89 pound per minute of particulates will leave the prototype scrubber presently installed at Dickerson. This system has a capacity of 92.5 MWe. Scaling this to the entire complex (present and proposed) gives an emission rate of 21.7 pound per minute or .164 Kg/second. This corresponds to a removal efficiency of about 99.5%, which probably is a lower limit. Again, it is possible to scale to the SO<sub>2</sub> emission and obtain the predicted ground level concentration of particulates. This assumes dispersion as a gas which is a fairly good assumption since most of the particulates not removed are extremely small. To obtain the number of  $\mu\text{gm}/\text{M}^3$  of particulates, multiply the concentration of SO<sub>2</sub> in

ppm by 527.5. For a configuration of two 850-foot stacks, this gives a maximum 24-hour value of  $6.38 \mu\text{g}/\text{M}^3$  compared with a State standard of  $140 \mu\text{g}/\text{M}^3$ . The predicted annual average is  $.20 \mu\text{g}/\text{M}^3$  compared with a standard of  $65 \mu\text{g}/\text{M}^3$ .

In its passage through the scrubbers, there will be a slight change in the character of the particulates. Some of the fly ash will be replaced by other material, such as solid  $\text{MgSO}_3$  and  $\text{MgO}$ .

In conclusion, it is believed that the levels of particulates due to the expanded plant will be well below the applicable standards.

### Sulfates

$\text{SO}_2$ , the major pollutant emitted from coal-fired fossil fuel power plants, is unstable in air at normal temperatures with respect to oxidation to sulfates. Among the sulfates produced may be the acid sulfates, sulfuric acid and bisulfate ion. Two general routes are available for the oxidation. One involves either a photochemical or thermal gas phase oxidation. The other route is the catalysis by transition metal ions in thin solution films on the surface of fly ash particles. The most abundant catalytic metal available is iron (Ref. 5-9). The rates measured for the gas phase processes are 1% to 2% per hour (Ref. 5-10). While all of the  $\text{SO}_2$  is eventually converted to sulfate, the slow rate would allow some of the  $\text{SO}_3$  and  $\text{H}_2\text{SO}_4$  produced to be neutralized by atmospheric ammonia to form  $(\text{NH}_4)_2\text{SO}_4$  (Ref. 5-11), as well as dispersing the material over a wide enough area to allow the concentrations to be considerably reduced. However, the fact that all of the  $\text{H}_2\text{SO}_4$  is not neutralized is attested to by the low pH rainfalls measured in industrialized areas of the world (Ref. 5-12).

The low rate of gas phase oxidation would prevent any appreciable production of  $\text{H}_2\text{SO}_4$  in the vicinity of a power plant where sulfur compounds are in higher concentrations. However, conversion rates have been measured near TVA plants that are 1% to 2% per minute (Ref. 5-13). Since these high rates are observed only at relative humidities high enough to allow condensation of water on fly ash nuclei, the probable mode of oxidation is the solution phase, metal ion catalyzed reaction (Ref. 5-9).

To assess the possible impact of conversion of  $\text{SO}_2$  to sulfates near the Dickerson plant, we have developed a numerical model of the oxidation process in coal-fired power plant plumes. Only the solution phase process has been considered since this is the one that could potentially give high concentration near the plant where  $\text{SO}_2$  concentration is high. The model calculates the percent oxidation for relative humidities near saturation because these are the circumstances that will give the maximum percent conversion. The calculation would apply to emission of the plume into a naturally high humidity atmosphere, a saturated plume due to a wet  $\text{SO}_2$  scrubber system, or to a stack plume mixing with the plume from a cooling tower. The numerical results should only be regarded as approximate due to the extreme complexity of the processes involved and the dearth of experimental data taken in either the laboratory or field. However, by comparison with the TVA data where some measurements are available (Ref. 5-13), and after making several environmentally conservative assumptions, we will show that the amounts of sulfate produced are below levels regarded as possibly dangerous by either EPA or several states.

While a number of studies have been done on the oxidation of  $\text{SO}_2$  by metal ions (Ref. 5-11), the only even semi-quantitative study of the kinetics of the reaction in an oxygen-saturated system with iron as the catalyst is that of Neytzell-DeWilde and Taverner (Ref. 5-14). This data has been applied to a rate law of the form

$$\frac{d(\text{SO}_4^{-2})}{dt} = \frac{k(\text{Fe}^{+3}) (\text{SO}_2)}{(\text{H}^+)} \quad (5, 11)$$

where  $\frac{d(\text{SO}_4^{-2})}{dt}$  is the instantaneous change in

concentration of total sulfate species with time,  $(\text{Fe}^{+3})$  is the concentration of iron in the +3 oxidation state,  $(\text{SO}_2)$  is the total concentration of sulfur in the +4 oxidation state,  $(\text{H}^+)$  is the hydrogen ion concentration, and  $k$  is a rate constant. The concentrations have units of moles/liter and the rate constant has units of reciprocal minutes. An approximate allowance was made for ionic strength effects, although the data provided by Neytzell-DeWilde and Taverner were skimpy at best. The temperature dependence of the rate constant was also determined. Therefore, the rate constant is a function of ionic strength and temperature.

This constant was used in a modified form of the rate equation given by Foster which is in terms of the chemical species encountered in a power plant plume (Ref. 5-9). This equation is

$$R = k P_{\text{SO}_2} W V/H$$

Where R is the rate of oxidation, k is the rate constant,  $P_{\text{SO}_2}$  is the partial pressure of  $\text{SO}_2$ , W is the concentration of  $\text{Fe}^{+3}$  in the water film around the fly ash particles, V is the total volume of water on all particles, and H is the hydrogen ion concentration.

V is determined from an assumed fly ash particle size of one micrometer, the approximate weight of soluble material in the fly ash including sulfates produced by the oxidation, and the equation relating equilibrium droplet size and relative humidity given by Mason (Ref. 5-16).

The concentrations of  $\text{Fe}^{+3}$  and  $\text{H}^{+}$  are given by consideration of the chemical equilibria among the various species in the droplet at a given volume and temperature. The chemical species considered are  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{CO}_2$ ,  $\text{Fe}^{+3}$ ,  $\text{Fe}(\text{SO}_4)^+$ ,  $\text{Fe}(\text{SO}_4)_2^{-1}$ ,  $\text{HSO}_3^-$ ,  $\text{SO}_4^{-2}$ ,  $\text{HSO}_4^-$ ,  $\text{NH}_4^{+2}$ ,  $\text{H}^{+}$ , and  $\text{HCO}_3^-$ .

Since the rate of conversion at a given point is a function of the partial pressure of  $\text{SO}_2$ ,  $\text{CO}_2$ , and temperature, it is necessary to account for the changes in these parameters as the plume disperses. To describe the dispersion, we have used, with appropriate modifications, the expressions given by Hanna (Ref. 5-17), since this was optimized to describe the dispersion near a stack where most of the dispersion takes place.

Our model was calibrated by adjusting a parameter which controls the rate at which the volume of water in a droplet reaches equilibrium with the ambient relative humidity for a given solute loading, until the percent of  $\text{SO}_2$  converted equals the high humidity case measured by TVA (Ref. 5-13) with all other parameters the same. The conversion of  $\text{SO}_2$  to sulfate measured by TVA in this case was 55.5%.

A parameter study on the model with this calibration indicated that the percent conversion was relatively insensitive to all meteorological parameters except the relative humidity. The model predicts that the rate of

oxidation is extremely rapid immediately after leaving the stack, but drops off to almost nothing in the first few minutes as the plume disperses. This is due to the rapid drop in the partial pressure of  $\text{SO}_2$ . The dominant conversion route soon switches from the solution phase to the gas phase process where the percent integrated rate of conversion over the plume is approximately independent of the partial pressure of  $\text{SO}_2$ .

When the model was run for the proposed two new units at Dickerson under the same conditions as the high conversion TVA case, it was found that the total conversion of  $\text{SO}_2$  to sulfate was 5%. This is due primarily to the very low fly ash emission from the proposed Dickerson plant.

If we assume that this number applies to the entire plume and plant under all meteorological conditions (even though high humidity conditions do not occur most of the time), we may calculate the maximum ground level concentration of sulfates at the various averaging times. These values can be compared with an EPA suggestion of  $8-12 \mu\text{g}/\text{m}^3$  of sulfate for annual exposure (Ref. 5-18),  $10 \mu\text{g}/\text{m}^3$  of  $\text{H}_2\text{SO}_4$  in Missouri for 24-hour exposure (Ref. 5-19), and  $30 \mu\text{g}/\text{m}^3$  of  $\text{H}_2\text{SO}_4$  in Montana for 24-hour exposure (Ref. 5-19). There is no Maryland standard for sulfate. The values computed for Dickerson are  $.07 \mu\text{g}/\text{m}^3$  for the annual,  $2.4 \mu\text{g}/\text{m}^3$  for the 24-hour, and  $12 \mu\text{g}/\text{m}^3$  for the one hour. These numbers are for a Dickerson configuration of one 850-foot stack for the present plant and one 850-foot stack for the proposed plant. The computed values should be considered to be upper bounds.

The actual chemical nature of the various sulfate species is harder to assess. They would probably be a mixture of  $\text{H}_2\text{SO}_4$ ,  $\text{NH}_4 \text{HSO}_4$ ,  $\text{CaSO}_4$ , and  $\text{Fe}_2 (\text{SO}_4)_3$ , although the relative proportion of each are not clear.

We conclude that there appears to be no danger from sulfate exposure in the area around the Dickerson Plant complex.

#### Acid Rain

For some years there have been reports of very acidic rainfall in Northern Europe and the United States (Ref. 5-12). Values as low as 2.8 pH units have been

reported in Europe (Ref. 5-20). This should be compared with a "normal" pH of 5.7 for water in equilibrium with atmospheric  $\text{CO}_2$  (Ref. 5-21). These observations have led to concern that there could be a problem from highly acidic rain from rain drops falling through the stack gas plumes of power plants.

The major work on  $\text{SO}_2$  washout has been done by Battelle Northwest (Ref. 5-22, 23). In their field study at the Keystone Generating Station, they found that there was no clear correlation between the direction of the plume and the pH of the samples. Chemical analysis of the rain samples indicated little dissolved  $\text{SO}_2$ . The results were interpreted to indicate outgassing of  $\text{SO}_2$  as the drop left the plume. While the  $\text{SO}_2$  was in the drop, there was little oxidation to sulfate which would have the effect of retaining the acidity of the sulfurous acid (formed by  $\text{SO}_2$  and water) within the drop. Most of the acidity observed could be accounted for by the amount of sulfates in the drop if they were at least part  $\text{H}_2\text{SO}_4$ , sulfuric acid. The pH in the drop is determined by the interplay of sulfate species, dissolved and atmospheric  $\text{SO}_2$ ,  $\text{NH}_3$ , and  $\text{CO}_2$  in much the same way as in sulfate oxidation as was described above. Since the pH and sulfate concentrations are approximately the same upwind or downwind of the plant, it would indicate that the plant is not a major source. The lowering of pH's would appear to be more related to the regional sources of such material as  $\text{SO}_2$  rather than a single localized source.

To confirm this work in the Dickerson area, we have conducted a series of measurements of rain water pH around the present Dickerson Generating Station. Samples were collected on five days in the winter, spring, summer, and fall of 1973. These samples consisted of rain collected over a period of about three hours at sites 1, 2, and 3 miles from the plant under the plume centerline, 1/2 to 1 mile to the side of the plume, and 1-2 miles upwind of the plume. The pH of the samples was then determined with a Leeds & Northrop pH meter. At no time was the pH under the plume more than 0.5 pH units more acidic than that at the upwind site. The lowest pH observed under the plume was 4.01. The pH at the upwind site on this occasion was 3.30. The more basic nature of several of the underplume samples may be partially related to the slightly soluble calcium oxide in the fly ash as was observed during a TVA study (Ref. 5-13). Similar effects have been observed in comparisons of rural and urban rainfall samples (Ref. 5-24).

In conclusion, the data does not indicate that the pH of rain water is appreciably lowered around the present Dickerson plant. While the pH of the rainfall may be lower than that expected in an absolutely "clean" area, there is no indication that this results from the power plant. Rather, it appears to be associated with the industrialized nature of the eastern United States. These measurements in the vicinity of a 555 MWe power plant are in agreement with the results in the vicinity of the 1800 MWe Keystone plant.

The small amount of data available indicate that these power plants are not significantly affecting the acidity of the rain in neighboring areas since measurements of rain water pH upwind were comparable to those of downwind rain collections and since the pH values in the vicinity of the 555 megawatt Dickerson plant were comparable to those in the vicinity of the 1800 megawatt Keystone plant.

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## APPENDIX C

### THE RELATIONSHIP OF STACK HEIGHT TO SCRUBBER RELIABILITY AND MODULARIZATION

#### INTRODUCTION

It is desirable, whenever possible, to configure the plant to provide some inherent reserve for equipment failure. This question has been examined relative to modular size and reliability of scrubbers. PEPCO has indicated, informally, that scrubber modules will likely be designed to provide stack gas cleaning for 200 MWe sections of the generating system.

#### ANALYSIS

##### Existing Plant

When all three scrubbers are operating at the level of 90% removal, the  $\text{SO}_2$  in the stack is .1 of that produced by the furnace. If a scrubber fails,

$$\begin{aligned}\text{fraction of } \text{SO}_2 \text{ to stack} &= 1/3 + 1/10(1/3) + (1/10)(1/3) = \\ &1/3 + 2/30 = 12/30 = .4 \times \text{Total } \text{SO}_2\end{aligned}$$

i.e., the sulfur emission is increased by a factor of 4. Reference to Table 5-10d indicates that the max GLC with scrubber (for Config. 6 with 400-ft. stack) is 34 ppb. In the event of scrubber failure, this increases to 136 ppb which is well in excess of 100 ppb. Our analysis does not indicate its frequency of occurrence. Table 10-d shows only 17 ppb for an 850-ft. stack (Config. 6) with scrubber active, which becomes 68 ppb in the event of scrubber failure. The reserve capability in the event of scrubber failure provided by the 850-ft. stack is readily apparent.

##### Proposed Plant Expansion

If the proposed expansion is scrubbed in 200 MWe modules, nine such modules are required. Again with scrubbers operating, .1 of the  $\text{SO}_2$  generated is emitted through the stacks. If a scrubber fails,

$$\begin{aligned}\text{fraction of } \text{SO}_2 \text{ through stack} &= 1/9 + 8(1/10)(1/9) = 18/90 = \\ &.2 \times \text{Total } \text{SO}_2\end{aligned}$$

i.e., the SO<sub>2</sub> emission is doubled. Reference to Table 5-10d, Config. 9, shows that the maximum with scrubbers operating would be 61 ppb; this becomes 122 ppb with one scrubber inoperable. This would occur at the point of max impact only one time per month. Hence the failure of a 200 MWe modularized scrubber on the proposed plant (including Units 4 and 5), will not lead to violations of the Maryland one-hour standards at the most impacted point.

#### CONCLUSION

These calculations, based on a hypothetical but realistic scrubber modularization, indicate the reserve environmental protection to be achieved by increasing the stack height of the existing plant. The hypothetical configuration of scrubbers treated here is considered to be a reasonable one, but it does not represent design agreement with PEPCO.

Also, it should be recognized that the higher levels of GLC occur infrequently and are correlated to unfavorable meteorological conditions. The probability of a scrubber failure being coincident with such unfavorable meteorology is low.

Nevertheless, the concurrent existence of a scrubber failure and adverse meteorology may require a reduction in plant operation (shutdown of unscrubbed units). It is, therefore, important that scrubbers and stack gases be monitored, see Section 8, and that the time to detect and repair scrubbers be kept as low as possible.